Whitman (C. O.)

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COMPANION PRINCIPLES OF ALL PROGRESS.

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AMERICAN BIOLOGY.

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FIRST LECTURE.

SPECIALIZATION AND ORGANIZATION,

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By C. O. WHITMAN.

A HEALTHY faith in the progress of biology presupposes a correct understanding of the tendency to specialize. It is important to know not only that specialization is a necessity, but a necessity that need not be feared. It may sound a little paradoxical to assert, that this tendency means union as well as separation; but it is only a truth illustrated in the most familiar facts of science and of every-day life. Let us look at some of the broader aspects of this tendency, in order to learn whither it is carrying us and what its implications are.

Naturalists are long accustomed to the idea that the living body represents a commonwealth of cells. The metaphor is based, not upon superficial or fanciful resemblances, but upon analogies that lie at the very foundation of organic and social existence. On the same grounds that the sociologist affirms that a society

is an organism, the biologist declares that an organism is a society.

A society is an organized whole, the unity of which consists in, and is measured by, the mutual dependence of its members. The living body is an organization of individual cells with the same bond of unity. The principle of organization in both cases is the division of labor or function. The primitive social aggregate — the undifferentiated germ of society — is composed of practically like units, with like simple needs. Every one is a factotum, fulfilling all needs in and for himself. It is all self-dependence and no mutual dependence. The coherence of the whole is so slight that it can break up into as many parts as there are individuals, without the sacrifice of a single tie or condition essential to existence.

In course of time, division of labor comes into play, and with it social organization has its beginning. The different members, instead of doing all sorts of work, and aiming only to supply their own individual wants, begin to limit themselves to such work as their tastes, capacities, surroundings, etc., commend to them. This concentration of effort, which Coleridge, in his theory of life, has defined as "the tendency to individuation," both strengthens and improves the productive power, thus enabling a few to do the work of many. Each class of specializers produce in excess of their own needs, and through the exchange of these surplus products the needs of all are supplied.

The social integration that accompanies such division of labor may best be seen under conditions conceived as simple as possible. Let it be assumed that we have

an aggregate of a hundred individuals, equal in competency and capacity for work, and all living under like conditions. Let us assume that the necessities of existence for each member require ten kinds of labor in equal quantities.

Now as long as each individual fulfils all ten needs, there will be no division of labor, but rather a divison of energy and correspondingly inferior products. The aggregate will represent a mere chance collection of independent individuals, not a whole of mutually dependent parts. But introduce the division of labor, and see how social integration follows. To take a simple form of division, we will suppose the aggregate divided into ten equal groups, one for each kind of work.

We still have the same workers, the same energy expended, the same work accomplished, and the same needs fulfilled; all we have done is simply to divide the labor instead of the time, and distribute it in such a way that each person gives his entire time to one work instead of dividing it among ten. The change, in itself considered, looks extremely simple and insignificant; but, when measured by the consequences entailed, its importance becomes at once apparent. Each work is now accomplished by ten men instead of a hundred, with the result that each individual fulfils only one-tenth of his own needs, and depends upon his fellows for the rest. Instead of jacks-at-all-trades, we now have specialists working under a social compact, which makes each individual the indispensable servant of every other. The co-ordination of individuals is such as to maintain a complete consensus of functions; which is the fundamental trait of a perfectly organized community, and

its chief distinction from a purely gregarious aggregate.

If the members of such a community, in adaptation to the conditions it imposes, should become so far differentiated as to lose the power of providing for more than one or two of the ten necessities of existence, the social unity would become as inviolable as the physiological unity of the higher organisms. Break it, and every member would soon perish, just as certainly as every cell would die if the body were irreparably injured. The social organism might endure the loss of a limited number of its members, as the animal organism survives the death of individual cells and even the loss of certain organs. These losses may be repaired, in the one case by substitution, in the other by regeneration.

If reparation fails, all the remaining parts suffer in proportion to their dependence on the parts lost. In either case, the more complete the division of labor, broadly speaking, the more perfect becomes the unity of parts, the more complete the coincidence of the individual with the general welfare.

The parallel is more complete than our assumed case is suited to illustrate. We have considered only the two extremes of a series, and have not allowed for any connection through intermediate stages of development. But division of labor is not an artificial affair arbitrarily fashioned to our convenience; it is not a thing of human device, for it antedates both the written and the unwritten history of our race. In the organic world, its development has been as slow and as long as the rise of the beings now inhabiting the earth; in the human

race, its period of growth coincides with that of civilization itself.

We cannot know the circumstances of its first introduction. We assume that opportunities for the first steps in the division of labor presented themselves fortuitously, and that, the opportunities being given, the inherent advantages of the principle in the struggle for existence would be quite enough to secure it the aid of natural selection.

The principle carries with it two grand advantages — two primary conditions of progress. First, the concentration of energy; and secondly, the economical combination of energies. The one holds the possibilities of intensifying and improving; the others, the possibilities of utilizing and augmenting. These conditions and their contained possibilities, given with the division of labor, are *the* possibility, not only of all social, but also of all organic evolution.

We may now go still further and assert that the evolution of the cell, the relatively simple structural unit of the organic world, would have been an impossibility without the division of labor. Imperfect as our knowledge of the cell still is, it is now certain that it has an organization based upon a division of function.

There is already an overwhelming amount of concurrent evidence to show that the nucleus is the real seat of the hereditary tendencies; and the deeper we penetrate into the complexities of its structure, and the more we study its internal transformations and movements, the more evident it becomes that the nucleus has had its evolution, which carries the subdivision of labor still farther back.

Our knowledge, so far as it goes, points to the conclusion that division of labor is not only co-extensive with life, but also coeval with it. Indeed, we should be on the side of all the probabilities, in assuming that the simplest possible form of living matter presupposes this principle. We are not, of course, to confound the principle with life itself, nor with the cause of life ; it is only a condition or means to an end. The universal correlate of division of labor is union of the laborers. It always means specialization, and always implies organization.

Thus the paradox resolves itself. As Herbert Spencer long ago pointed out in his Social Statics, "progress is toward complete separateness and complete union," and "the highest individuation is joined with the greatest mutual dependence."

As you see, the principle is one which may re-inaugurate itself, as often as a new order of units is evolved with needs that can be most economically and efficiently served by a co-operative union. We do not know how many times this may have happened before the cell order of beings arose ; but the general course of development following this stage, we are now very confident about.

Some of these cells, finding independent nomadic life congenial, have persistently declined every temptation to part with individual freedom. They have kept their freedom, but with it the low estate of unaided individual effort. Precious freedom that, which excludes all those larger possibilities of life which we see unfolded in the organic world.

Others preferred company to isolation, and herded

together in roving colonies. Some of these were dominated by a gregarious instinct only, and have clung tenaciously to self-freedom, refusing to make any sacrifice of personal independence for the sake of a physiological union. A few such aggregates, whose freedom has been the forfeit of all advancement, still survive, as exemplified in some members of the Volvox family. In Gonium, for example, the colony consists of a few (4–16) flagellate cells, adhering together in plate-like form, each self-moving, self-feeding, and self-propagating.

Among these colonial aggregates, there were some, however, which found out how to take one or two simple steps in labor partnership, and thus advanced to a rudimentary kind of composite individuality. An interesting example is seen in the famous Volvox of Leeuwenhoek, in which the evolutionists of last century found a confirmation of their idea, that the germs of plants and animals are preformations in miniature, incased one within the other. The division of labor is here of such an elementary order, that, as Bütschli has suggested, we may look upon a Volvox colony as a near ally of those simple forms from which all the higher plants as well as the Metazoa arose.

The Volvox colonies, composed of numerous individuals, often more than a thousand, are attached to the inner surface of a colonial envelope, at equal distances. In each colony we find two kinds of cells ; one with two flagella for locomotion, the other without such appendages, fulfilling the work of reproduction. This single division of labor makes one class of individuals the propagators of the species, the other the preservers

of the colony. Neither class can dispense with the services of the other; and this dependence of part upon part gives the colony a certain physiological unity. But the integration of the colony is of such a simple order, that we might conceive it splitting up into as many independent colonies as it contains times the least number of cells of both sorts necessary to maintain the physiological connexus. Although in practice, we could not carry the division so far, still we know that artificial, if not spontaneous, division would be possible without destroying the physiological unity necessary to the continued existence of the severed parts.

One feature of labor-division in Volvox deserves mention here, chiefly as foreshadowing more complex conditions seen in higher forms. It is the alternation of agamic with gamic generation. The agamic reproductive cells are all alike, and correspond to parthenogenetic ova; while the gamic generation is represented by two distinct kinds of cells answering to ova and spermatozoa, and conjugation is necessary to development.

This alternation of parthenogenesis with hermaphroditic gamogenesis — is not, we may be sure, an acquisition of the colony; it is rather to be regarded as a combination of features that originated separately and successively among the unicellular ancestors of the colony. Parthenogenesis must have been the primitive mode of reproduction; gamogenesis undoubtedly originated secondarily in adaptation to infusorial conditions of life.

This sequence of generations is common enough among the unicellar Protozoa; and the colonial forms exhibit it as an inheritance of their component cells.

The parthenogenetic colony presents itself, then, as an aggregate of individuals with differentiated, but undivided, reproductive work; the hermaphroditic colony explains itself as an aggregate of individuals with differentiated and sexually-divided reproductive work. The association of both sexes in the same colony is an accident of aggregation; for obviously we might have, in fact do have, dioecious as well as monoecious colonies.

The protozoan colony of the Volvox type, represents the old infusorial system of labor-division and, superadded thereto, the colonial stage of what we may call the intercellular system — which runs through all the higher organisms.

With the intercellular system is given a higher order of units, capable of combining and recombining to form successively higher orders, each carrying all previous systems of labor distribution with its own superimposed thereon. The ascending series ranges through all diversities of form and all complexities of structure between the simplest cell-colony and man. Cells combine into tissues, tissues into organs, organs into organisms, organisms into organic as well as social aggregates, and these in turn into higher units. While the higher units are entering into new combinations, their components of the next order below, of the next below that, and so on to the lowest, may be undergoing simultaneously special modifications, each struggling to keep up its own internal and external adjustments, but always in subordination to the welfare of the entire organism. When we contemplate the finished mechanism, the product of all these consentaneously and yet unconsciously directed energies, these millions of individual minim

workers, uniting in such intimate fellowship as to constitute an indissoluble whole — a real conscious intelligent unity — with powers so far transcending those of its units that we can form no conception of the special combinations from which they result, — when we contemplate this miracle of co-adjustments among myriads of units, among these systems of units, and these systems of systems, we are not disposed to ridicule the judgment that once refused to believe that natural forces could produce such wonders, and took refuge from the difficulties that beset every mechanical theory in the doctrine of preformation.

If our microscopical aids have enabled us to know that organisms are not simple unfoldings of pre-existing structures, and have revealed the fact that every developing germ actually re-enacts the wonders of a new creation, still it is no less an unscrutable mystery than before. Indeed one must credit the preformationists with having perceived and emphasized the real difficulty in the way of any rational theory of generation. We endeavor to meet it, by assuming, not pre-existing rudiments, but pre-existing hereditary units ; not predelineations, but potentialities, of structure. Predeterminations of some kind or other are a logical necessity, and so there is some analogy between our position and that of Bonnet, Haller, and Cuvier, and other evolutionists of the old school, although we are compelled to regard the process of development as one of epigenesis, as conceived by Aristotle, Harvey, John Hunter, and Casper Friedrich Wolff. The difference between the two schools reduces itself to the difference between potentialities and actualities ; and although the difference as understood

by the contending parties is utterly irreconcilable, still we can understand how, by modifying our potentialities in one direction and our actualities in another, the difference might be brought near a vanishing point.

Whether we look at the successive stages connecting the relatively homogeneous germ with the completed organism, or at the palæontological succession of forms, we see that progress in the organic world is always from the less to the more heterogeneous. As division of labor advances, complexity of structure increases, and the ties of mutual dependence multiply and strengthen. In a word, the most characteristic trait of evolution is, that increasing *division* of labor conditions increasing *union* of the laborers. Division and union, differentiation and integration, specialization and organization, march hand in hand.

The same truth comes perhaps more clearly into view, when, taking the protozoan colony for our starting-point, we run up the scale of animal organizations. Passing on from the Volvox colony, we soon come to an instructive stage represented in the common fresh-water Hydra. Although we now know that the organization of this animal is far from being as simple as was supposed by its discoverer, Trembley, and by other naturalists of his time, who regarded it as a connecting link between plants and animals, still it affords a striking illustration of the fact, that *physiological unity is a thing of degrees, incomplete according as the division of labor is low.*

A single division of labor, in advance of what we saw in Volvox, makes Hydra an unmistakable Metazoön, placing it fairly on the main line of animal evolution. It is the separation of the digestive from the other functions

which characterizes the Hydra stage. In correlation with this important step, we have one grand and several minor structural features introduced. The digestive cells arrange themselves together in the form of a tubular sack open at one end, thus taking the first step towards a rudimentary alimentary canal. Around this sack, the remaining cells station themselves, forming another sack inclosing the first. The sacks are in close contact, and the walls of the outer one are continuous with those of the inner one at its open end, so that the inner sack may be regarded as an infolding, such as we might rudely represent by pushing in the end of a glove-finger. If the material were elastic, so that we could draw out the double wall around the open end into a number of arm-like extensions, we should have a fair model of the Hydra body with its tentacles.

The cells constituting the inner sack, called the entoderm, are in the most favorable situation for attending to the food-supply of the entire cell community; and natural selection has constrained them to specialize in this direction until they have become inoperative in other ways, and even incapable of doing anything else. Trembley succeeded in turning these creatures inside out; and as they lived on after such treatment, he inferred that the functional differentiation of the two layers was so slight that ectoderm and entoderm could exchange places and works. The mistake has only recently been corrected by a Japanese naturalist. Dr. Ischikawa of Tokyo has shown conclusively that Hydra cannot live long turned inside out, and that, if left to itself after the operation, it soon turns itself back into its normal condition. This act of recovery escaped the

observation of Trembley, and of others who repeated his experiments; and hence the unity or individuality of the Hydra community of cells has generally been estimated too low.

That the two layers carry functions fundamentally distinct and non-interchangeable, and that the co-operative combination of the two sets of functions is necessary to existence, — is, in fact, the very essence of the Hydra personality, — is shown by still another fact brought out by Mr. Ischikawa. It is generally taught that Hydra may be divided *ad libitum*, and that each fragment will have the power to regenerate the whole individual. But it turns out that there is a very definite limit to such possibilities, which cannot be overstepped without annihilating individuality and extinguishing even the germ of it. An isolated piece of either layer is incapable of regenerating the individual. The mutual dependence of these two layers is such that they must go together or perish. Carry artificial division in any direction that does not sunder these complementary parts, and repeat the operation as often as you like, the smallest fragments in which this vital connection is preserved will represent, potentially at least, the personality of Hydra. This personality comprises a certain number of functional powers; and hence the minimum number of cells combining these powers in vital relations represents all the essential elements of individuality. The fertilized ovum unites all these powers as potentialties, and it is therefore the individuality in germ. If the ectoderm cells, like the entoderm, were all alike, the essentials of a Hydra might be said to exist in a single pair of cells, one from each layer; but of course we could not hope to isolate such a pair of cells in vital union.

The remarkable thing about such an individuality is, that a hundred of them may be added together and the sum total will be but one; and yet you may divide this *one* into a hundred *ones*.

Mr. Ischikawa succeeded in forcing two individuals into complete and permanent coalescence; and for aught we can see, the experiment might be repeated indefinitely. One Hydra was turned inside out, and then pushed into the mouth of another until the digestive sacks of both were brought together one within the other. A bristle was then thrust transversely through both bodies to prevent separation. In the course of a few days, the two bodies were completely merged in one, and the resulting individual was a perfect personal unity, bearing two sets of tentacles as the only mark of its double origin.

Having seen in what the essential unity of Hydra consists, we can readily understand why such an individuality may not be weakened by division or strengthened by doubling. A society of a hundred individuals with ten labors, distributed as we supposed, would represent a unity with ten essential points of union. Now we could double the number of members without increasing the points of union; and we could divide the whole community into ten communities, each with as complete a functional unity as that of all combined.

In the case of Hydra, we could divide more freely, because the points of union are fewer. Now what I wish to emphasize here is this: *The more the points of union multiply in a social or an organic body, the more complex and extended becomes the integration of its parts, and the less susceptible it is to such divisions and fusions*

as we have described. Bear in mind as we go on, that every point of union is a point of division, or specialization in labor.

Our supposed social aggregate, as I have said, admits of division into ten independent communities. If, however, we multiply the points of union by ten, *i.e.*, if we suppose each labor sub-divided into ten specialties, each member of the aggregate will fulfil only one-hundredth of his own needs, and will depend upon his ninety-nine associates for the rest. The mutual dependence is not only ten times as great, it is also ten times as extensive, for each individual is now a necessity to ninety-nine instead of nine others, and the entire aggregate becomes an indivisible whole.

The same processes are followed by like results among the cell-constituents of an organism, only here we rarely find such simple, and never such complete, uniformity in numerical relations. We find no organism in which the division of function exactly coincides with the number of its component units. Both the division of labor and its distribution here tend to adjust themselves, first of all, in harmony with the primary necessities of existence; and secondly, in correspondence with that complex of relations, conditions, and needs, both internal and external, which hold all the possibilities of improving existence, and rising above it to conscious life and intelligence.

In the organic association of cells, nutrition and reproduction take precedence in determining the direction of development. The needs which centre in them are, as a rule, best served, not by giving the whole of a given kind of work to a single cell, but by

dividing it more or less equally among many cells, scattered or grouped according to the nature of the work. Nature is provident as well as bounteous, and so she determines the number of workers not only with reference to ordinary needs, but also with a view to emergencies. The cell cannot work on indefinitely. Exhaustion follows exertion ; rest and recuperation are as necessary to the cell as to an individual ; hence the need of relays. The cell has its own term of existence, which is usually much shorter than that of the organism ; hence the need of substitutes. So each class of specialized cells may greatly exceed in number the actual needs of the moment. One of the best illustrations of this fact is seen in the reproductive cells, which are often so enormously in excess of use, that they are scattered in the water or the wind, with not one chance in a thousand of ever fulfilling the purpose of their existence. All such profuseness, however, has its meaning, even though it only neutralize accident, and so insure a few the realization of their proper destiny.

But these hosts of cells suffice for only one of the many varieties of reproductive work. They are called reproductive cells, not to indicate monopoly of the entire work, but pre-eminence merely in one important branch of it. Propagation of the species is their task ; but this becomes a monopoly only among the higher forms of life. The same work may be accomplished by budding and fission, processes which prevail very largely among plants and many of the lower animals, usually supplemented, however, by the more general process of reproduction by means of specialized cells.

But the generation of the species, which follows such

different courses, each of which goes on into almost endless sub-division, is not the whole of reproduction. Reproduction of the species of course includes all other kinds of reproduction; nevertheless it is as distinct from them as the individual is from its component cells. The individual may be the product of a single cell, but, once formed, the heterogeneous components must severally have their own methods of reproduction, otherwise the organism could not keep up its reserves, nor supply the places of exhausted, disabled, or worn out laborers. These specialized modes of reproduction, as varied and as distinct as the histological elements of the organism, although derived from the process which continues the species, yet differ from it in this important respect, that their products are isogeneous rather than heterogeneous.

This distinction is already well marked in Hydra, where we find the entoderm cells so specialized that they can reproduce only cells of their own kind. How different it is with the ova, which reproduce all kinds of cells represented in the Hydra community.

Certain kinds of work exclude the power of reproduction, and such cases call for special provisions of still another class. The loss of such power by any class of cells is generally made good by a closely allied class, or by the younger cells of the same class. Such reserves may play a relatively passive part, until the time arrives for them to take the place of their predecessors; and they may be capable of assuming any one of several different roles. Again Hydra furnishes us with a simple illustration. The superficial ectoderm cells of Hydra, consisting of nettle-cells, nerve-muscle

cells, etc., are replaced by deeper and younger cells, called "intermedial." The reproductive cells have the same origin.

The work of reproduction then is not confined to any one or two classes of cells; it is divided and subdivided in endless detail, carried all through the organism, and distributed independently of most other labors. Its elaboration in this or that direction may be correlated with a system of morphological differentiations, so extensive and involved that a whole course of lectures would be required to elucidate the subject. Take the genital system of the vertebrates, or that of forms no higher than the annelids, and you will find no end of problems yet to be settled. What complicated cycles of generation have been followed by many parasitic forms, especially among the worms, and what wholesale modifications of structure in answer thereto. How devious have been the paths of generation in insects, and how wonderful the metamorphoses attending them. How diverse the ways of multiplication among the Tunicates and Cœlenterates, and what puzzling successions and combinations of forms have here tried the sagacity of naturalists.

What peculiar corporation aggregates are represented in Siphonophore colonies, of which we have a most beautiful example in the Portuguese-man-of-war. How long it has taken to decide between the "poly-organ theory" of Eschscholtz, Huxley, Müller, and Metschnikoff, and the "poly-person theory" of Vogt, Leuckart, Kölliker, Gegenbaur, and Haeckel. The complex of reproductive processes in one such colony would still bear a life-time of research, and not be

exhausted then. Who is able to trace out the reproductive alternations and metamorphoses of such simple yet strange forms as the Dicyemids and Orthonectids, supposed by some, though probably erroneously, to stand as an intermediate group between the Protozoa and the Metazoa?

And when we descend to the Protozoa themselves, we find the reproductive cycles specialized in ways as varied as the forms of life. Then behind and underlying the whole of this reproductive work, from Protophyte to Phanerogam, from Protozoa to man, are those intensely interesting phenomena of caryokinesis, which are at once the most varied and the most uniform expression of reproductive energy that modern research has yet revealed.

I need not dwell longer on this subject. We have not found the beginning of reproductive work, nor can we see an end either to its divisions or to the structural unities and divergencies correlated therewith.

We might now turn to nutrition and sketch the general features of its specializations and coördinations; but we should only find the same principles illustrated in new directions, and might get weary without getting wiser.

I will therefore at once try to bring the leading thought to a focus, and then very briefly point out its application.

Division of labor is the principle underlying all organic as well as all social progress. The development of the principle brings with it mutual dependence of the working units; and hence, every step in advance leads necessarily to that closer integration of the units

which merges their individualities into an individuality of a higher order. The tendency towards unity, as specialization advances is nowhere more strikingly illustrated than in the progress from the lower to the higher segmented animals. In the lower annulose types, the individual represents a chain of segments or somites, which we may regard as so many individuals which have arisen as buds, one after the other, from before backwards, but have remained connected in the order of origin. These somites retain their individuality to such an extent that they are not killed by artificial separation, and indeed often undergo spontaneous fission.

As we glance along the line of forms terminating in the Myriopods, the Crustaceans, the Insects, and the Arachnids, we find the individualities of the somites more and more subordinated to that of the chain they compose. There is a progressive consolidation, which, in its extreme phases, more or less completely obliterates the traces of articulation. The illustration might be extended to the vertebrates, but that would be needless. Let me add only, as one of the broadest conclusions to be drawn from such facts as we have been considering, that *the grade of specialization attained in any group of organisms determines its rank in the scale of life and intelligence.*

In each order of units, specialization seems to have its limit in the highest possible integration of its component elements. When this limit is reached, progress is arrested. The only way then open for advance lies in combining these units into units of a higher order. In this combination is given the possibility of a

new system of specializations and integrations, with correspondingly high grades of life. The final stage of each order of units represents a complete individuality, which cannot be divided without destruction. So we advance from certain "physiological units" to the indivisible cell, from the cell to the indivisible organism composed of cells, from the highest units here to those of the social order.

It is unnecessary to enlarge further upon these facts. It remains only to point out their bearing in relation to the biological sciences.

The days when naturalists could presume to take all nature for a subject of study and meditation are a long way behind us. The cosmogonists of olden times engaged single-handed with all the mysteries of the universe. We honor them for their heroic efforts, ineffective as they were from misdirection. At the expense of centuries of baffled efforts, the lesson began at last to be learned, that division of the problem facilitates progress. That a knowledge of the whole presupposes a knowledge of the parts, was a simple enough fact; but it took a long time to turn it into practice.

Division of labor in the sciences, as elsewhere, has been a thing of slow growth, self-originating, self-perpetuating, and self-regulating. It has taken possession of the biological sciences, and presides over their onward march, just as it determines and directs social and industrial progress. It is simply an economical principle, the growth of which began with, advances with, and will always have its limitations in, an actual need — the need of concentrated attention. This need

in turn has its limits in our power to improve the methods of investigation. The tendency, then, is regulated by the necessities and advantages of the investigator; and although we may not be able to fix definite limits to its growth, we are not the less certain that it has such limits, and that there is no danger either of a wholesale reaction or of our ever specializing to pieces. As in the organic and social worlds, so in the scientific, there are centripetal forces that keep pace with the centrifugal ones; and the danger of any science flying into disconnected atoms is about as dreamy and remote as the dissolution of the earth itself.

The movement in the direction of separation is general and, as it *now* seems to us, rapid. Cuvier thought that division of labor characterized the natural science of his day; but the movement was then in its earliest infancy. If you wish to know how extensive it has now become, you should look at the ponderous volumes of the "Zoological Record" or the "Naples Jahresbericht." When you reflect that it requires such massive volumes to record the bare titles and a brief abstract of the work of a single year, you realize how impossible it is for any one naturalist to cover the whole ground, or even to read the hundredth part of what his collaborators have to report.

Naturalists then are no longer cosmogonists, but specialists. This being the fact, what is to be done in view of it? Where lies the remedy for every danger of narrowness that may lurk in the tendency to specialize? How is the range of vision to be kept free and broad while focussing attention on some one point of the field? If one specialty absorbs our whole

time and energy, how are we to keep its general bearings and relations in full view? Will organization of any kind within our reach effect this? If our specialties are parts of a whole, then this whole must be representable by one or more modes of combination. That kind of organic association which permits each unit to work for itself while making it the servant of all the rest, must be a possibility.

It must be evident to every one who is capable of understanding the situation, that *union* is just as essential a part of the law of progress as division. If specialization is a necessity, so is organization. But there is this difference between the tendencies, — that the one precedes the other and comes into recognition first. Specialization has already forced its way to the front, and is nearly everywhere recognized as a necessity; organization follows, but lags lamentably behind the needs of the times.

The general principle of coöperation has long been at work. The naturalists of all countries are brought into coöperative relations through journals and other scientific publications. Every year multiplies these points of union, and draws the scattered workers into closer mutual dependence. Cut off these indispensable media of communication, and that unity of action on which progress now depends would at once come to an end. Of course the unity of action in so extended a body cannot be complete. Duplication of work will now and then occur, but the waste in this direction is fast becoming reduced to a minimum.

The tendency to specialization is rapidly developing among our journals. This is seen especially in such

journals as the *Zoölogischer Anzeiger*, the *Biologisches Centralblatt*, the *Anatomischer Anzeiger*, the *Journal* of the *Royal Mic. Soc.*, the *Zeitschrift f. wis. Mikroskopie, &c.* Manifestly all such specialization is led by the coöperative spirit.

But it is not to the general tendency so much as to our own special need that I would now direct attention. We have now reached a point where our advance, both individually and collectively, depends, far more than ever before, upon the privileges, the opportunities, and the many peculiar advantages inherent in the principle of coöperative work.

Among the ways of bringing together our scattered forces into something like organic union, the most important, and the most urgent at this moment, is that of a national marine biological station. Such an establishment, with a strong endowment, is unquestionably *the* great desideratum of American biology. There is no other means that would bring together so large a number of the leading naturalists of the country, and at the same time place them in such intimate helpful relations to one another. The larger the number of specialists working together, the more completely is the organized whole represented, and the greater and the more numerous the mutual advantages.

Just consider what such an organization implies. It means, first of all, a permanent staff of investigators, with laboratories equipped for special research, and with facilities for extending observation to different points of our varied coast. It means boats, and all needful appliances for collecting, dredging, etc. It means a corps of trained collectors at the service of the investigators.

It means a comprehensive working library; ample funds for serial and monographical publications; funds for travelling research; and resources for coöperative work with similar stations in other parts of the world. It means, further, all those important aids and accessories of investigation, such as conservators of material, assistants in microtomical and other mechanical work, skilled draughtsmen, photographers, lithographers, and so on to the end of all the needs of such an organization.

Create such conditions of work, and how biology would flourish. Specialization would characterize the individual members; but organization would dominate the aggregate. In place of the weakness of isolation, we should have all the power of union. There would be economy of time, money, service, physical and intellectual strength. The productive power of each individual would be intensified and augmented beyond calculation by that of every co-laborer; for while the units ministered to the whole, the power and influence of the whole would redound to the benefit of each. The difference between isolation and a union of this kind, is like that which separates the solitary cell from a highly developed organism, or the nomadic aggregate from civilized society. We need *viva voce* contact for incentive, for stimulation, for inspiration, and especially for maintaining that "*moving equilibrium*" of our specialized forces which constitutes progressive scientific life; and organization in the direction I have roughly indicated will accomplish all these ends.

In conclusion, let me say that the establishment of such a station as I have sketched will probably never

be effected through the unaided effort of any one person. But individual effort, though weak alone, has in the growing aggregate a cumulative power that often surprises expectation. Let every one feel, therefore, that his or her personal interest in the matter may be just what is required to make the combined effort of all effective in converting possibilities into actual realizations, and in giving to specialization its consummation in organization.